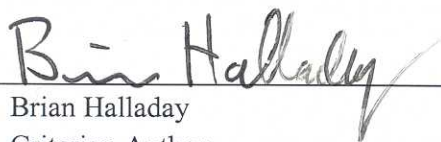


**CRITERION 507**  
**LIGHTNING PROTECTION SYSTEMS**

**SIGNATURES**



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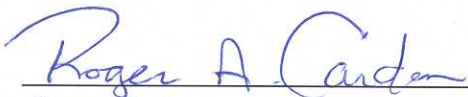
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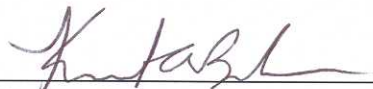
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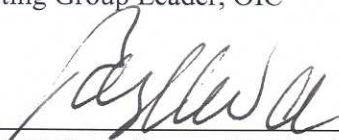
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**RECORD OF REVISIONS**

<b>Revision No.</b>	<b>Date</b>	<b>Description</b>
0	08/27/98	Initial Issue. Replaces 3.7-600, Rev. 0. Deleted Forward, Statement of Authority, Maintenance Standard Update, 1.0 General Requirements and 2.0 LANL Maintenance Policy Documents.
1	04/01/02	This revision includes the addition of a Table of Contents, the use of Basis Statements in Sections 6 and 7, and incorporates a review of ORPS & NRC lessons learned 1/1/95 to 6/2000.
	04/16/02	This revision incorporates the latest format of the Criterion 101: Writer's Guide Revision 3.
	4/17/02	Inclusion of comments and changes from Maintenance Subcommittee review.
	5/22/02	Rewording of Requirement Training Section 6.2 and inclusion of AHJ per Maintenance Committee request.
	5/31/02	Inclusion of comments and changes from Maintenance Subcommittee
	7/16/02	Change in Definitions
2	7/21/03	Addition of Requirements for structures with Faraday Cage or Faraday-like Shield in explosive areas (Section 6.3)  Incorporation of all resolved comments from PEER and POC/FM reviews.

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**CRITERION 507****LIGHTNING PROTECTION SYSTEMS****1.0 PURPOSE**

This Criterion establishes the minimum requirements and best practices for operation and maintenance of lightning protection systems at LANL. This document addresses the requirements of LIR 230-05-01 (Ref. 10.4), “Operations and Maintenance Manual.”

Implementation of this Criterion satisfies DOE Order 430.1A (Ref. 10.2) for the subject equipment / systems – DOE Order 430.1A (Ref. 10.2), “Life Cycle Asset Management,” Attachment 2 “Contractor Requirements Document,” Paragraph 2, Sections A through C, which in part require UC to “...maintain physical assets in a condition suitable for their intended purpose” and employ “preventive, predictive, and corrective maintenance to ensure physical asset availability for planned use and/or proper disposition.” Compliance with DOE Order 430.1A is required by Appendix G of the UC Contract.

Additionally, implementation of this Criterion should help reduce hazards to life and property that can result from the deterioration or derangement of lightning protection systems in LANL facilities.

**2.0 SCOPE**

This document covers the inspecting, testing, and maintaining of all lightning protection systems at scheduled intervals, in accordance with ANSI/NFPA 780 (Ref. 10.9) and DOE M440.1-1 (Ref. 10.3). This Criterion does not address corrective maintenance actions required to repair or replace equipment.

**3.0 ACRONYMS AND DEFINITIONS****3.1 Acronyms**

<b>AHJ</b>	Authority Having Jurisdiction
<b>ANSI</b>	American National Standards Institute
<b>CFR</b>	Code of Federal Regulations
<b>DOE</b>	Department of Energy
<b>LIR</b>	Laboratory Implementing Requirement
<b>LPI</b>	Lightning Protection Institute

<b>LPR</b>	Laboratory Performance Requirement
<b>NFPA</b>	National Fire Protection Agency
<b>O&amp;M</b>	Operations and Maintenance
<b>PMI</b>	Preventive Maintenance Instruction
<b>PP&amp;PE</b>	Personal Property and Programmatic Equipment
<b>RP&amp;IE</b>	Real Property and Installed Equipment
<b>SME</b>	Subject Matter Expert
<b>SSC</b>	Structures, Systems, and Components
<b>SSS</b>	Support Services Subcontractor
<b>UC</b>	University of California
<b>UL</b>	Underwriters Laboratory

## 3.2 Definitions

**Air Terminal.** That component of a lightning protection system that is intended to intercept lightning flashes; lightning rod. (NFPA 780, 2-2 [Ref. 10.9].)

**Bonding.** An electrical connection between an electrically conductive object and a component of a lightning protection system that is intended to significantly reduce potential differences produced by lightning currents. (NFPA 780, 2-2 [Ref. 10.9].)

**Explosives Facilities.** A structure or defined area used for explosives storage or operation as defined by the DOE Explosives Safety Manual (DOE M440.1-1.)

**Ground Terminal.** That component of a lightning protection system such as a ground rod or a counterpoise conductor that is intended to provide electrical contact with the earth. (NFPA 780, 2-2 [Ref. 10.9].)

**Lightning Protection System.** A complete system of air terminals, conductors, ground terminals, interconnecting conductors, surge arresters, and other connectors or fittings required to complete the system.

**“Faraday” or “Faraday Like”.** Electrostatic shield composed of wire mesh or a series of parallel wires, usually connected at one end to another conductor which is grounded.

**Subject Matter Expert.** The person in FWO-MSE with the knowledge and ability to guide Laboratory and DOE personnel in the area of lightning protection as delegated by the LANL Fire Marshal.

**Surge Arrester.** A protective device for limiting surge voltage by discharging or bypassing surge currents. It also prevents continued flow of follow current while remaining capable of repeating these functions (NFPA 780, 2-2 [Ref. 10.9].) Surge arresters are installed on electrical service entrances, antenna cables, telephone service entrance and other wire service entrance (fire alarm and security).

**Transfer Impedance.** The ratio of the voltage applied at one pair of terminals of a network to the resultant current at another pair of terminals, all terminals being terminated in a specific manner. Calculation of transfer impedance in Faraday –shield systems predicts the magnitude of electric fields produced inside a building by a lightning strike.

## **4.0 RESPONSIBILITIES**

### **4.1 FWO - Maintenance and System Engineering (MSE)**

- 4.1.1** FWO-MSE is responsible for the technical content of this Criterion and monitoring the applicability and the implementation status of this Criteria and either assisting the organizations that are not applying or meeting the implementation expectations contained herein or elevating their concerns to the director(s).

*Basis:* LIR 301-00-01.11; Issuing and Managing Laboratory Operations Implementation Requirements and Guidance, Section 5.4, OIC Implementation Requirements.

- 4.1.2** FWO-MSE shall provide technical assistance to support implementation of this Criterion.

### **4.2 Facility Manager**

- 4.2.1** Responsible for operations and maintenance of institutional, or Real Property and Installed Equipment (RP&IE) under their jurisdiction, in accordance with the requirements of this document.
- 4.2.2** Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that may be assigned to the FM in accordance with the FMU-specific Facility/Tenant Agreement.

### **4.3 Group Leader**

- 4.3.1** Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document, which are under their jurisdiction.
- 4.3.2** Responsible for system performance analysis and subsequent replacement or refurbishment of assigned PP&PE.

### **4.4 Authority Having Jurisdiction (AHJ) – Fire Marshal**

- 4.4.1** The AHJ is responsible for providing a decision on a specific technical question regarding this criterion.

## **5.0 PRECAUTIONS AND LIMITATIONS**

### **5.1 Precautions**

This section is not intended to identify all applicable precautions necessary for implementation of this Criterion. A compilation of all applicable precautions shall be contained in the implementing procedure(s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards/precautions that may not be immediately obvious.

**5.1.1** Follow the safety precautions listed in Appendix C of NFPA 780 when inspecting, testing, or maintaining lightning protection systems. Provide for fall protection OSHA 29CFR1910 Subpart D and LIR 402-10-01.5 Hazard Analysis and Control for Facility Work.

**5.1.2** DOE M440.1-1, DOE Explosives Safety Manual, requires an approved lightning protection system for all facilities used for storage, processing, and handling of explosive materials where operations cannot be shut down during electrical storms and personnel evacuated.

Additional details on Faraday and Faraday Like cages can be found in Chapter X of the DOE Explosives Safety Manual.

**5.1.3** Work performed from aerial lifts or similar devices shall conform to 29CFR 1910.67.

### **5.2 Limitations**

The intent of this Criterion is to identify the minimum generic requirements and recommendations for SSC operation and maintenance across the Laboratory. Each user is responsible for the identification and implementation of additional facility specific requirements and recommendations based on their authorization basis and unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, vendor O&M requirements and guidance, etc.).

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities shall implement the requirements of DOE Order 4330.4B (Ref. 10.1) as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or CFR identified above.

## **6.0 REQUIREMENTS**

Minimum requirements that Criterion users shall follow are specified in this section. Requested variances to these requirements shall be prepared and submitted to FWO-MSE in accordance with LIR 301-00-02 (Ref. 10.5), "Variances and Exceptions to Laboratory Operations Requirements," for review and approval. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgment, safety matters, and operations and maintenance experience drive the requirements contained in this section.

### **6.1 Operations Requirements**

**6.1.1** No operations requirements.

### **6.2 Maintenance Requirements**

**6.2.1** Personnel responsible for maintenance, inspection and testing of lightning protection systems for explosive facilities must be knowledgeable of and properly trained in the fundamentals described in NFPA 780 and DOE M440.1-1 (Explosives Safety Manual)

*Basis:* DOE M440.1-1, Chapter X, Section 3, Inspection and Testing of Lightning Protection System

#### **6.2.2 Explosives Facilities**

**6.2.2.1** Develop procedures and execute a program for lightning protection system maintenance according to the requirements of NFPA 780 and the minimum requirements of this document. Visual inspection of lightning protection systems should be conducted every seven months and shall be conducted at least annually.

*Basis:* DOE M 440.1-1, Chapter X, Section 3.0 b.1. (Ref. 10.3)

**6.2.2.2** Electrical testing for lightning protection systems shall be conducted at least every forty-seven (47) months.

*Basis:* DOE M 440.1-1, Chapter X, Section 3.0 d. (Ref. 10.3)

#### **6.2.2.3 Lightning Protection System Modifications**

Lightning protection system shall be inspected whenever any alterations or repairs are made. Record modifications to lightning protection systems in the record drawings and other pertinent documents.

*Basis:* NFPA 780, B-1.1.1. (Ref. 10.9)



### **6.3 Structures with Faraday Cage or Faraday-Like Shield Lightning Protection System**

- 6.3.1** Bonds and surge suppressors shall be visually inspected every two years to validate the installation and serviceability.

*Basis:* DOE M440.1-1, Chapter X, Section 3.0 a

- 6.3.2** A visual inspection shall be performed on surge suppression devices and other LPS components after all lightning flash events where there are visible indications on the structure of a lightning strike and any time there is modification, maintenance or repair to the structure, or penetration that could affect the SSD. or LPS component.

*Basis:* DOE M440.1-1, Chapter X, Section 3.0 b

- 6.3.3** Electrical resistance measurements of visible bonds shall be taken every five years. Such measurements are also required when there are visible indications on the structure that an act of nature such as an earthquake, tornado, flood, etc. or other act could have affected the integrity of the bonds; and any time modification, maintenance or repair to the structure, penetration of LPS components require the bond or connection to be broken.

*Basis:* DOE M440.1-1, Chapter X, Section 3.0 c

- 6.3.3.1** Bond resistance shall be less than 1.00 ohm. A 1.5 ohm resistance is acceptable where necessary for joining of existing structural elements by rebar bonding.

*Basis:* DOE M 440.1-1, Chapter X, Section 3.0 c.2

- 6.3.3.2** Tighten to manufacturer recommended torque or replace bonds which do not meet the resistance requirement of 6.3.3.1.

*Basis:* DOE M 440.1-1, Chapter X, Section 3.0 c.2

- 6.3.4** Transfer impedance measurements shall be taken every fifteen years. Such measurements are also required when there are visible indications on the structure that an act of nature such as an earthquake, tornado, flood, etc. or other act could affect the integrity of the internal structure bonds; and any time there is major modification, maintenance or repair to the structure.

*Basis:* DOE M440.1-1, Chapter X, paragraph 3.0 (x)

## **7.0 RECOMMENDATIONS AND GOOD PRACTICES**

The information provided in this section is recommended based on acceptable industry practices, codes and standards, manufacturers recommendations, operating experience, DOE/LANL Lessons Learned program or engineering judgement and should be

implemented by each user based on his/her unique application and operating history of the subject systems/equipment.

Appendices A and B to this document contain recommended lightning protection system inspection and testing schedules that facility managers may use.

## **7.1 Operations Recommendation**

### **7.1.1 Known Lightning Discharge**

A lightning protection system should be inspected following any known lightning discharge to the system.

*Basis:* NFPA 780, B-1.1.1. (Ref. 10.9)

## **7.2 Maintenance Recommendations**

### **7.2.1 Maintenance and Operational Testing Logs**

Record routine inspections and tests using logs for each lightning protection system.

*Basis:* NFPA 780, B-1.5. (Ref. 10.9)

### **7.2.2 Maintenance and Testing Procedures**

Prepare specific maintenance and testing procedures and other work-related documents (e.g., lightning protection system drawings) for each maintenance category. Use inspection and test procedures to provide appropriate work directions and to ensure that maintenance is done safely, efficiently, and according to this maintenance document. LPI documents may be used as a guide.

*Basis:* NFPA 780, B-1.5. (Ref. 10.9)

### **7.2.3 Inspections**

For structures not subjected to DOE M440.1-1 (Ref. 10.3) it is recommended that lightning protection systems be visually inspected at least annually. Complete in-depth inspections of all systems should be completed every three to five years.

*Basis:* NFPA 780, B-1.1.2. (Ref. 10.9)

*Basis:* DOE M 440.1-1, (see paragraph 6.2.1.1, 6.2.1.2). (Ref. 10.7)

## **8.0 GUIDANCE**

### **8.1 Maintenance Guidance**

- 8.1.1** Appendix B of NFPA 780 provides the following guidance for inspecting and maintaining lightning protection systems:

#### **Appendix B Inspection and Maintenance of Lightning Protection Systems**

*This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.*

#### **B.1 Inspection of Lightning Protection Systems.**

**B.1.1 Frequency of Inspections** It is understood that all new lightning protection systems must be inspected following completion of their installation. However, it is also very important to make periodic inspections of existing systems. The interval between inspections should be determined by such factors as the following:

- (1) Classification of structure or area protected
- (2) Level of protection afforded by the system
- (3) Immediate environment (corrosive atmospheres)
- (4) Materials from which components are made
- (5) Type of surface to which the lightning protection components are attached
- (6) Trouble reports or complaints

**B.1.1.1** In addition to regular periodic inspections, a lightning protection system should be inspected whenever any alterations or repairs are made to a protected structure, as well as following any known lightning discharge to the system.

**B.1.1.2** It is recommended that lightning protection systems be visually inspected at least annually. In some areas where severe climatic changes occur, it may be advisable to visually inspect systems semiannually or following extreme changes in ambient temperatures. Complete, in-depth inspections of all systems should be completed every three to five years. It is recommended that critical systems be inspected every one to three years depending on occupancy or the environment where the protected structure is located.

**B.1.1.3** *In most geographical areas, and especially in areas that experience extreme seasonal changes in temperature and rainfall, it is advisable to stagger inspections so that earth resistance measurements, for example, are made in the hot, dry months as well as the cool, wet months. Such staggering of inspections and testing is important in assessing the effectiveness of the lightning protection system during the various seasons throughout the year.*

**B.1.2 Visual Inspection.** Visual inspections are made to ascertain the following:

- (1) The system is in good repair.
- (2) There are no loose connections that might result in high resistance joints.
- (3) No part of the system has been weakened by corrosion or vibration.
- (4) All down conductors and ground terminals are intact (nonsevered).
- (5) All conductors and system components are fastened securely to their mounting surfaces and are protected against accidental mechanical displacement as required.
- (6) There have not been additions or alterations to the protected structure that would require additional protection.
- (7) There has been no visual indication of damage to surge suppression (overvoltage) devices.
- (8) The system complies in all respects with the current edition of this standard.

**B.1.3 Complete Testing and Inspection.** Complete testing and inspection includes the visual inspections described in B.1.2 and the following:

- (a) Tests to verify continuity of those parts of the system that were concealed (built in) during the initial installation and that are not now available for visual inspection.
- (b) Ground resistance tests of the ground termination system and its individual ground electrodes if adequate disconnecting means have been provided. These test results should be compared with previous or original results or current accepted values, or both, for the soil conditions involved. If it is found that the test values differ substantially from previous values obtained under the same test procedures, additional investigations should be made to determine the reason for the difference.
- (c) Continuity tests to determine if suitable equipotential bonding has been established for any new services or constructions that have been added to the interior of the structure since the last inspection.

**B.1.4 Inspection Guides and Records.** Inspection guides or forms should be prepared and made available to the authority responsible for conducting inspections of lightning protection systems. These guides should contain sufficient information to guide the inspector through the inspection process so that he or she may document all areas of importance relating to the methods of installation, the type and condition of system components, test methods, and the proper recording of the test data obtained.

**B.1.5 Records and Test Data.** The inspector or inspection authority should compile and maintain records pertaining to the following:

- (1) General condition of air terminals, conductors, and other components
- (2) General condition of corrosion-protection measures
- (3) Security of attachment of conductors and components
- (4) Resistance measurements of various parts of the ground terminal system
- (5) Transfer impedance measurements at all required points (These records are required DOE M 440.1-1, Chapter 10, 3.0e.1.)

- (6) Any variations from the requirements contained in this standard
- (7) A diagram of the structure or room showing all points requiring measurements or visual inspection and location of surge suppressors (This is recommended by DOE M 440.1-1, 3.0.e.2.)

## **B.2 Maintenance of Lightning Protection Systems.**

**B.2.1 General.** Maintenance of a lightning protection system is extremely important even though the lightning-protection design engineer has taken special precautions to provide corrosion protection, and has sized the components according to their particular exposure to lightning damage. Many system components tend to lose their effectiveness over the years because of corrosion factors, weather-related damage, and stroke damage. The physical as well as the electrical characteristics of the lightning protection system must be maintained in order to maintain compliance with design requirements.

### **B.2.2 Maintenance Procedures.**

**B.2.2.1** Periodic maintenance programs should be established for all lightning protection systems. The frequency of maintenance procedures is dependent on the following:

- (1) Weather-related degradation
- (2) Frequency of stroke damage
- (3) Protection level required
- (4) Exposure to stroke damage

**B.2.2.2** Lightning protection system maintenance procedures should be established for each system and should become a part of the overall maintenance program for the structure that it protects.

A maintenance program should contain a list of more or less routine items that can serve as a checklist and establish a definite maintenance procedure that can be followed regularly. It is the repeatability of the procedures that enhance the effectiveness of a good maintenance program.

A good maintenance program should contain provisions for the following:

- (1) Inspection of all conductors and system components
- (2) Tightening of all clamps and splicers
- (3) Measurement of lightning protection system resistance
- (4) Measurement of resistance of ground terminals
- (5) Inspection or testing, or both, of surge suppression devices to determine their effectiveness compared with similar new devices
- (6) Refastening and tightening of components and conductors as required
- (7) Inspection and testing as required to determine if the effectiveness of the lightning protection system has been altered due to additions to, or changes in, the structure

**B.2.3 Maintenance Records.** Complete records should be kept of all maintenance procedures and routines and should include corrective actions that have been or will be taken. Such records provide a means of evaluating system components and their installation. They also serve as a basis for reviewing maintenance procedures as well as updating preventive maintenance programs.

- 8.1.2** Questions on interpretations of lightning protection codes should be addressed to the Subject Matter Expert in FWO-MSE, as delegated by the LANL Fire Marshal.
- 8.1.3** Provided it has been reviewed and approved by FWO-MSE, information on maintaining lightning protection systems may be found in the JCNNM Support Services Subcontractor (SSS) Preventive Maintenance Instruction; PMI 40-10-002 (Lightning Protection Systems), and may be used to implement a maintenance program that is compliant with the requirements of this document.

## 9.0 REQUIRED DOCUMENTATION

Maintenance history shall be maintained to include, as a minimum, the parameters listed in the Table 9-1 below:

**Table 9-1 Documentation Parameters**

<b>MAINTENANCE HISTORY DOCUMENTATION PARAMETERS</b>				
<b>PARAMETER</b>	<b>ML 1</b>	<b>ML 2</b>	<b>ML 3</b>	<b>ML 4</b>
<b>Maintenance Activities</b>				
Repair / Installation	X	X	X	X
PM Activities	X	X	X	X
<b>Inspection Records</b>				
Inspection Date	X	X	X	X
SSC Condition	X	X	X	X
General conditions of air terminals, conductors and other components	X	X	X	X
General conditions of corrosion-protection measures	X	X	X	X
Security of attachments of conductors and components	X	X	X	X
Resistance measurements of various parts of the ground terminal system	X	X	X	X
Any variations from the requirements contained in NFPA 780 or LANL Criterion 507	X	X	X	X
Condition of surge arresters	X	X	X	X
<b>Electrical Test Records</b>				
Electrical continuity of concealed components	X	X	X	X
Resistance between strategic points of the system	X	X	X	X
Ground resistance of ground terminals	X	X	X	X
Transfer Impedance Measurements for Faraday Cages	X	X	X	X

*Basis: Documentation of the parameters listed in Table 9-1 above satisfies the requirements of LPR 230-07-00, Criteria 2, (Ref. 10.6) which states; "Maintenance activities, equipment problems, and inspection and test results are documented". For ML definitions, see LIR 230-01-02.2.*

**10.0 REFERENCES**

- 10.1** DOE Order 4330.4.B, Maintenance Management Program
- 10.2** DOE O 430.1A, Attachment 2 “Contractor Requirements Document” (Paragraph 2, Sections A through C), a requirement of Appendix G of the UC Contract.
- 10.3** DOE M 440.1-1 Explosives Safety Manual, Chapter 10, Section 3.0
- 10.4** LIR 230-05-01.0, Operation and Maintenance Manual.
- 10.5** LIR 301-00-02.0, Exceptions or Variance to Laboratory Operation Requirements.
- 10.6** LPR 230-07-00, Maintenance History
- 10.7** LANL- Facility Construction Manual 16670
- 10.8** LANL ID No.00-033, LANL-LAAO/CPAP-00-01-LP-01, DOE/AL Annual ES&H Review
- 10.9** NFPA 780, Lightning Protection Code
- 10.10** LPI, Lightning Protection Institute, Arlington Heights, IL 60004-7700

**11.0 APPENDICES**

**Appendix A:** Lightning Protection System Maintenance Schedule

**Appendix B:** Lightning Protection System Recommended Maintenance Items



## APPENDIX A

## LIGHTING PROTECTION SYSTEM MAINTENANCE SCHEDULE

Parameter	ML-1    ML-2	ML 3    ML 4
	<b>Facilities used for storage, processing, and handling of explosive materials.</b>	<b>Non-Explosive Structures</b>
REF.	DOE M-440.1-1	NFPA 780 B-1.1.2
Visual Inspections	Should be conducted every seven months and shall be conducted at least annually	Recommended at least annually
Electrical Testing (earth resistance)	Should be conducted every 14 months and shall be conducted at least every 47 months.	Complete in-depth inspections of all systems should be completed every three to five years. It is recommended that critical systems be inspected every one to three years.

ML-1, ML-2, ML-3 and ML-4 indicate LANL management level category.

**APPENDIX B**

**LIGHTING PROTECTION SYSTEM RECOMMENDED MAINTENANCE ITEMS**

ITEM No.	ACTIVITY
1	Inspect air terminals.
2	Inspect bonds to metal bodies.
3	Inspect tee-splicers and other connectors.
4	Inspect through roof connectors.
5	Inspect cable holders.
6	Inspect down conductors and grounds.
7	Check for additions or alterations to structure.
8	Measure ground terminal resistance.
9	Test continuity of concealed parts.
10	Measure system resistance
11	Inspect surge arresters.